WHITE PAPER

Proposal to Change Hydrologic Unit Delineations over the Estuarine Waters of North Carolina

Coastal Subcommittee of the
N.C. River Basin Coordinating Committee
Natural Resources Conservation Service (USDA)

Randolph L. Ferguson, Chairman (NOAA)
H. E. Mew, Jr., Secretary (NCDENR, DWQ, GW)

North Carolina Geological Survey
Charles W. Hoffman
Cathleen Farrell

Division of Coastal Management
Chase Barnard
Sheila Balsdon

Division of Marine Fisheries
Elizabeth Noble

Division of Water Quality
Brannon Ketcham

United States Geological Survey
Silvia Terziotti
Lloyd Edwards

Natural Resources Con. Service
Sherman Biggerstaff

EXECUTIVE SUMMARY

In 1974 the U.S. Geological Survey developed an 8-digit hydrologic-unit system for classifying and identifying individual stream segments of the nation's rivers. These unit codes were subdivided in 1978, and again in 1995, by the Natural Resources Conservation Service (USDA) for use in water resource planning. Within North Carolina, certification problems with the 1995 delineations, particularly in estuarine areas, led to formation of an interagency committee to revise unit delineation methods over coastal waters. This white paper presents a science-based conceptual proposal for delineating hydrologic units over the estuarine waters of the State.

The proposed methodology uses geomorphology as a basis for delineating hydrologic unit boundaries. These boundaries outline ancient drainage patterns and drowned river valleys within the estuaries that still direct the flow of water to coastal inlets. The drainage patterns can be delineated using submerged geomorphic features, such as shoals, tidal deltas, inlets, and shoreface limits, which can be seen on bathymetric maps. These features reflect relic ridgelines, mixing basins, and outlets to the ocean.

To correct certification problems, the Subcommittee recommends two changes in the way 14-digit hydrologic units are currently delineated in the open-water areas of North Carolina's estuaries: (1) Modify current estuarine delineations to comply with the geomorphic criteria set forth in this report; and (2) Modify existing 8-digit and 11-digit HU associations to maintain continuity between headwater areas and discharge to the ocean.

Introduction

WHAT ARE HYDROLOGIC UNITS?

Hydrologic units (HUs) represent a systematic method of subdividing the nation's river basins into manageable accounting units for water resource planning, management, and research. These units are delineated by subdividing major river basins and regions into smaller drainage areas using ridge lines, or drainage divides, shown on topographic maps. The Environmental Protection Agency, and other federal and state agencies, are increasingly utilizing these units to identify resource problems and allocate remedial funding and research dollars.

NATURE OF PROBLEM

Problems in delineating hydrologic units arise over coastal waters and shorelines, where topographic maps show no clear ridge lines to map unit boundaries. This paper addresses that problem, proposing different techniques for delineating hydrologic units in estuarine waters.

OUTLINE OF REPORT

The report discusses evolution of the hydrologic unit concept, estuarine problems, and proposed solutions in the following sections:

- *Evolution of the hydrologic unit concept;*
- *How 14-digit hydrologic units are delineated;*
- *Delineation problems in estuarine areas;*
- *Geomorphic approach to hydrologic unit mapping in estuaries;*
- *Delineation and digitizing methodology; and*
- *Justification* and recommendations.

The report closes with a request for feedback on the proposed delineation techniques, both in terms of the scientific soundness and defensibility of the method, and with respect to the impacts such changes may have on existing programs.

Evolution of the Hydrologic Unit Concept

INITIAL DEVELOPMENT

In 1974 the U.S. Geological Survey's Office of Water Data Coordination (U.S. Department of Interior), under the sponsorship of the Water Resources Council, developed an 8-digit, nationally uniform, hydrologic unit system for classifying and identifying stream segments of the nation's rivers. An eight-digit hydrologic unit generally covers 700 or more square miles. In North Carolina these 8-digit units were mapped by the U.S. Geological Survey (U.S. Geological Survey, 1974).

EXAMPLE OF 8-DIGIT UNITS

These 8-digit units were divided into distinct subdivisions. For example, consider unit 03020201 in the upper Neuse River Basin. The first two digits of this unit, 03, represent the South Atlantic and Gulf "region." The 4-digit designation, 0302, is the Neuse-Pamlico "subregion." Six digits, 030202, are called the Neuse River "accounting unit." The full 8-digits are called "cataloging units." Figure 1 illustrates these designations.

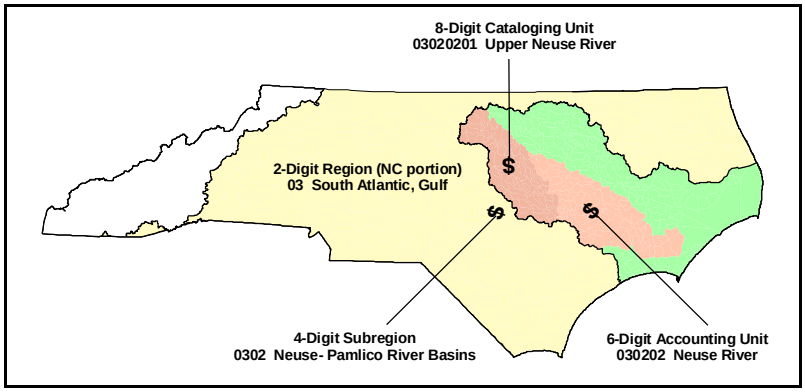

Figure 1. Example of 8-digit hydrologic-unit subdivisions.

In North Carolina the 6-digit units generally correspond to river basins, and the 8-digit units to subbasins.

EXPANSION OF CONCEPT

The 8-digit hydrologic unit codes were subdivided into 11-digit codes in 1978 by the U.S. Department of Agriculture (USDA) Soil Conservation Service for use in water resource planning. An eleven-digit code, or sub-watershed, is nominally sized at 250,000 acres, or 390 square miles. In 1994 the renamed Natural Resources Conservation Service (NRCS) expanded the hydrologic unit designation to 14 digits (6 to 78 square miles) to more accurately target project activities and to account for the results of these activities (Natural Resources Conservation Service, 1995).

CERTIFICATION PROBLEMS

The NRCS certifies hydrologic unit mapping within a state under national guidelines established by the NRCS National Cartography and Geospatial Center (NRCS NI 170-304). In North Carolina problems with estuarine mapping, including the mapping of unit boundaries along the centerline of streams, has delayed map certification.

COMMITTEE FORMATION

In August of 1999 the North Carolina NRCS office established an interagency River Basin Coordinating Committee (RBCC) to oversee revisions to the State's 14-digit hydrologic unit map. Revisions were expected to take a year, and result in national certification of the map. To specifically address estuarine mapping problems, a Coastal Subcommittee of the RBCC was formed. This report presents that committee's proposed techniques for mapping hydrologic units in North Carolina's estuarine areas.

How 14-digit Hydrologic Units are Delineated

METHODOLOGY USED

The 14-digit hydrologic units delineated in North Carolina subdivided the existing 11-digit hydrologic unit boundaries using 7.5 minute USGS quadrangle base maps (1:24,000 scale). Delineations followed criteria established by federal interagency agreement (NRCS 1995, revised 2000), Actual decisions on boundary placement were made with guidance from a review committee composed of federal and state agencies working in the state. The revised areal extent of 14-digit units ranges from approximately 3,000 acres (5 square miles) to 40,000 acres (62 square miles). In delineating these units, efforts were made to encompass the drainage areas of existing USGS stream gages.

CONSISTENCY CRITERIA

The consistent delineation of hydrologic units relies on three criteria:

- *Delineate drainage area boundary along topographic ridge lines;*
- *Preserve the stream network hierarchy; and*
- *Assure drainage to a point.*

EXAMPLE OF CRITERIA

Application of these criteria is illustrated in Figure 2, showing the Swift Creek watershed located south of Raleigh, N.C. Swift Creek is a tributary to the Neuse River and a headwaters watershed. The 11-digit watershed has been subdivided into 7 individual 14-digit hydrologic units by delineating unit boundaries along ridge lines. The network hierarchy of the watershed drainage is preserved in that each downstream hydrologic unit receives flow from all upstream units. In addition, each hydrologic unit discharges from the catchment at a single point, as shown by the arrows.

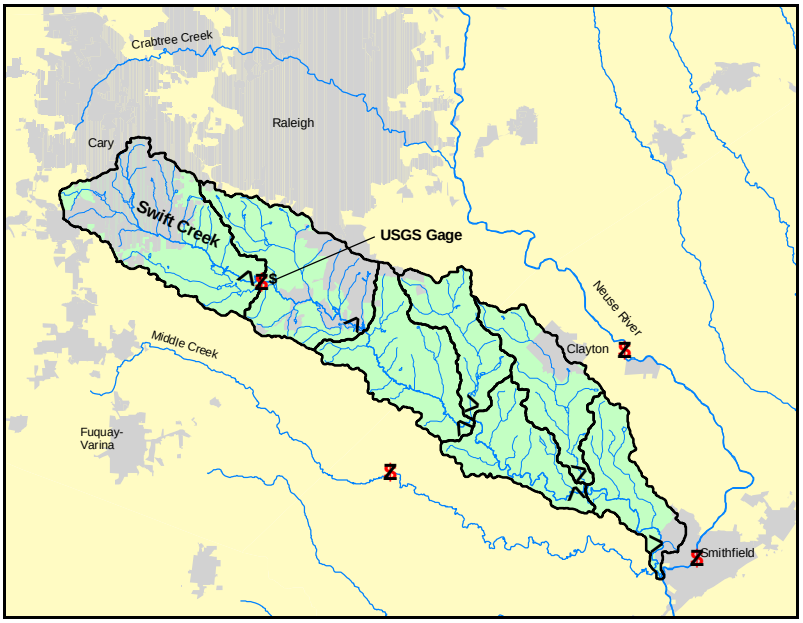

Figure 2. Example of 14-digit hydrologic-units Swift Creek watershed.

CRITERIA JUSTIFICATION

From a management perspective these three criteria provide several compelling arguments for integrating 14-digit hydrologic units into a watershed management strategy.

- *Delineations are made using a defensible, science-based method.*
- *The method preserves the "hydrologic" characteristics of the drainage.*
- *14-digit hydrologic units provide meaningful accounting units.*
- *These units can be used to target catchments needing remediation.*
- *The criteria assure a consistent, statewide strategy.*

RESTRICTIONS AND CERTIFICATION

It should be noted that developers of the 1995 14-digit HU map were restricted from altering the previously delineated 8-digit and 11-digit hydrologic units by the NI 170-304 guidelines. This restriction contributed to the present certification problems, as will be discussed in later sections.

Delineation Problems in Estuarine Areas

HOW ESTUARINE AREAS WERE MAPPED

The driving mandate behind hydrologic unit mapping was to classify *stream segments* of the nation's river system. When the USGS mapped North Carolina's bays and sounds, they simply crossed open-water areas with straight lines. When the NRCS subdivided these hydrologic units, to promote watershed planning, they had no guidelines for mapping the flat, uninhabited wetlands and marshes found in estuarine areas.

PROBLEMS WITH EXISTING ESTUARINE DELINEATIONS

The 14-digit estuarine hydrologic units that were mapped in 1995 are illustrated in Figure 3, with over-water units highlighted. An examination of these over-water delineations reveals several major problems that have impeded the widespread adoption, acceptance, and certification of this map.

1. *There is no drainage-to-a-point in delineated river-estuaries and sounds—boundary lines extend up the center of the river.*
2. *There is little relation between the delineated estuarine units and the stream network; i.e., the hierarchical criterion has been violated and there are no clear flow patterns.*
3. *There is no scientific basis for delineating these estuarine unit boundaries.*

These problems are illustrated in more detail in the following paragraphs.

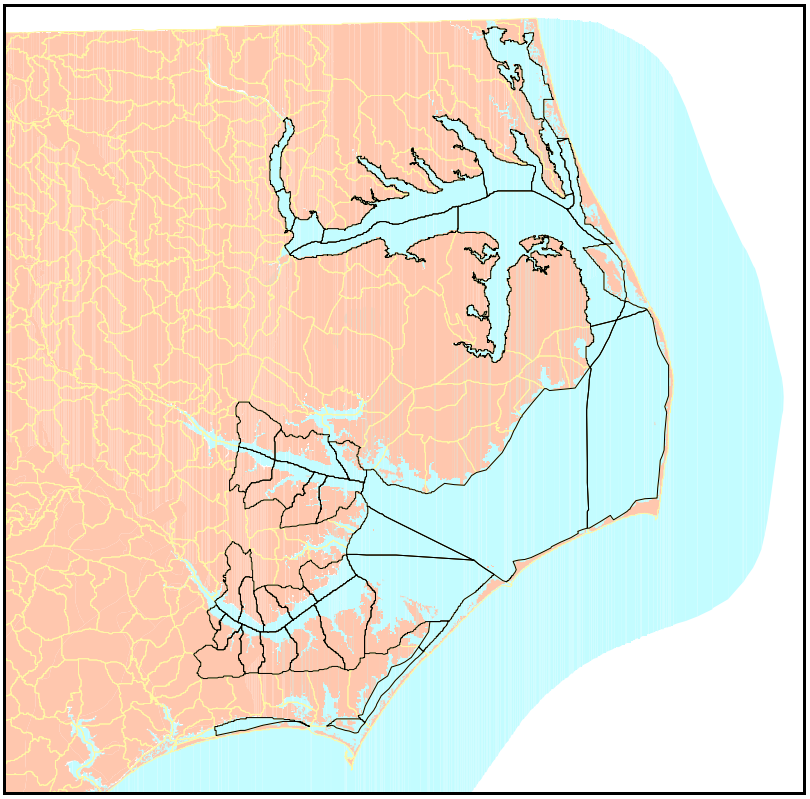

Figure 3. 14-digit hydrologic-units mapped in N.C. estuarine waters.

NO DRAINAGE-TO-A-POINT

The drainage-to-a-point problem is illustrated along the estuarine area of the lower Pamlico River where it discharges into Pamlico Sound, Figure 4. The problem here is that the center of the river was used as a hydrologic unit boundary, thus negating the catchment notion and single-point discharge from the unit. This problem compromises the "hydrologic" nature of these units and restricts their use in hydrologic modeling.

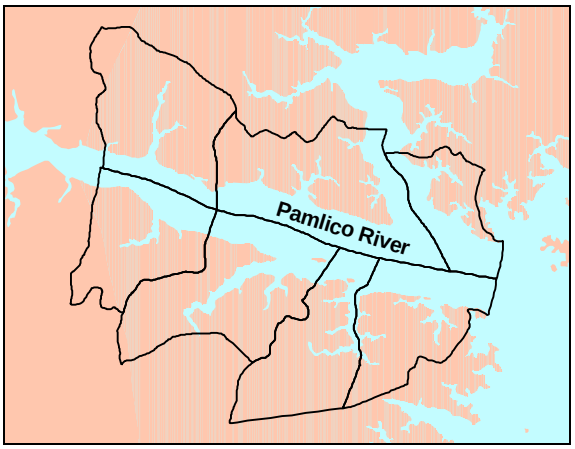

Figure 4. Example of 14-digit hydrologic-units not draining to a point.

NO STREAM HIERARCHY

Figure 5 illustrates the problem of not maintaining the hierarchical relationship between hydrologic units. In the current 14-digit mapping, the Neuse River Basin is abruptly terminated as it flows into Pamlico Sound, as shown in Figure 5. The units in red are grouped with the Neuse River Basin, while those in blue are grouped into the Tar-Pamlico River Basin. However, these blue units are more hydraulically connected to the Neuse than the Tar-Pamlico river system.

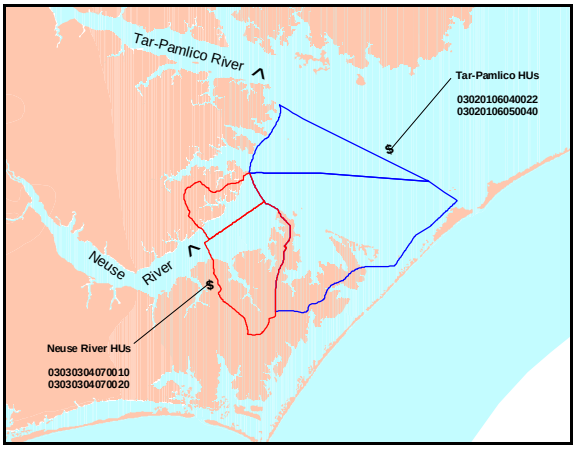

Figure 5. Example of non-hierarchical 14-digit units, Neuse River.

UNIT-BOUNDARY PROBLEM

The unit-boundary is a systemic problem concerned with how river basins were originally mapped in North Carolina. The White Oak River, shown in Figure 6, drains directly to the ocean, but is grouped within the Tar-Pamlico River Basin. The New River also drains to the ocean, has no hydraulic connection to the Cape Fear River, but is included in the Cape Fear River Basin. The state of North Carolina distinctly classifies both of these rivers within a White Oak River Basin, that is not recognized nor indexed in the federal hydrologic-unit system.

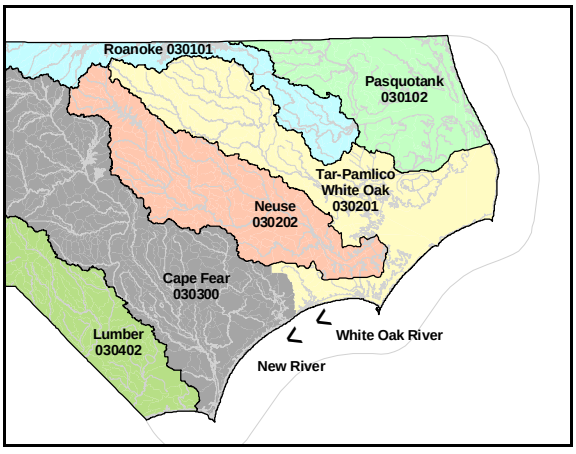

Figure 6. Example of unit-boundary problem, inclusion of coastal drainages.

CONSEQUENCES

These hydrologic-unit delineation problems in estuarine areas have diminished the utility and application of the stream classification system, to the detriment of consistent and cooperative watershed planning in North Carolina. From a management perspective these delineations:

- *mix land and water areas obscuring unit-area comparisons;*
- *are not "hydrologic" units that can be modeled;*
- *cannot be defended scientifically; and*
- *result in conflicting management, regulation, and investment strategies being imposed by different units of government.*

To address these problems, the Coastal Subcommittee sought a scientific underpinning for the delineation of estuarine hydrologic units.

Geomorphic Approach to Hydrologic Unit Mapping

OVERVIEW OF APPROACH

The Subcommittee proposes a revised methodology that uses geomorphology as a basis for defining HU boundaries. Bathymetric maps allow delineation of submerged geomorphic features, such as shoals, tidal deltas, inlets, and shoreface limits that direct the flow of water. The location of these features reflects Pre-Holocene (more than 10,000 years ago) drainage patterns that still affect the movement of estuarine waters.

RELIC TOPOGRAPHY INFLUENCES PRESENT-DAY FLOW PATTERNS

The relic features shown on bathymetric maps, Figure 7, provide insight into prehistoric coastal topography. At that time sea level was much lower, the ocean shoreline was located many miles to the east, and river valleys extended across present-day sounds. Over time rising sea level and sediment deposition tended to mask the underlying drainage patterns across the estuaries. Recent research has identified and mapped these drowned river valleys, or paleodrainages, as illustrated in Figure 8.

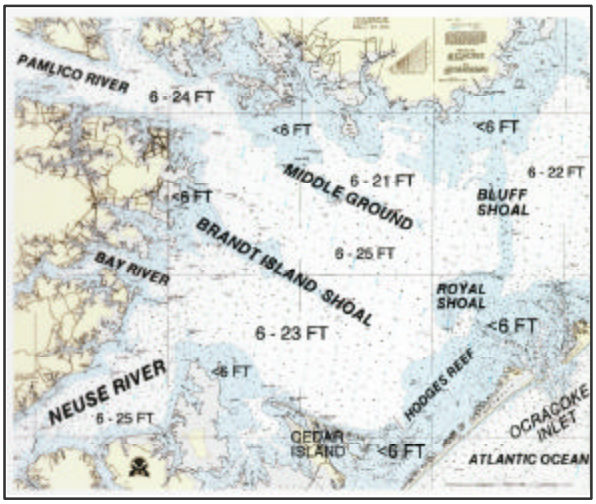

Figure 7. Bathymetric map illustrating shoals, tidal delta and inlet.

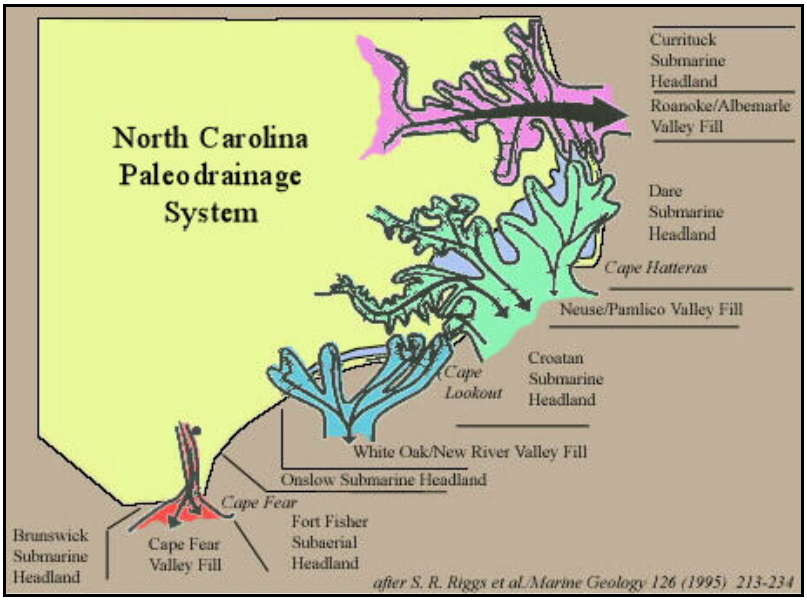

Figure 8. Pre-Holocene paleodrainage system in North Carolina.

UNDERSTANDING PALEODRAINAGES

The conceptual breakthrough for the Coastal Subcommittee in understanding paleodrainages was to mentally remove the estuarine waters and focus on the underlying topography. Present-day coastal-lagoon shoals could then be seen as ridge lines delineating drowned river-basin boundaries. Topographic depressions, representing drowned valley bottoms, were interpreted as present-day estuarine mixing basins. Flood-tidal deltas and inlets identified locations where estuarine waters drain to the ocean. Representatives from the North Carolina Geological Survey provided guidance to the Subcommittee in interpreting these geologic features.

CRITERIA FOR DELINEATING ESTUARINE HYDROLOGIC UNITS

Based on a geomorphic analysis of North Carolina estuaries, the Coastal Subcommittee proposes the following criteria for delineating 14-digit hydrologic units over water.

1. *At the estuarine shoreline, include shallow, near-surface, submarine areas to a depth of six feet within the adjacent subaerial, or over-land hydrologic units.*
2. *Extend land-based ridge-line delineations across open waters following the centerline of mapped shoals.*
3. *Delineate deeper estuarine mixing basins bounded by shoals or mapped shallow-water areas.*
4. *Delineate inlet/tidal delta systems as distinct hydrologic units using a six-foot depth criterion within the estuary and 30-foot depth on the ocean side.*
5. *Delineate barrier-island hydrologic units to the ocean-shoreface toe (assumed 30-foot depth).*

CRITERIA IMPLEMENTATION

Topographically delineated (land-based) HU boundaries were extended to a depth of six feet in adjoining estuarine waters. This is the approximate limit for light penetration sufficient to support submersed aquatic vegetation that might be impacted by waterborne nutrients and waste applied to the adjoining land. Barrier island HUs were mapped to the toe of the shoreface (approximated by the 30-foot contour) in order to include the dynamic, submerged portion of these islands. An example of 14-digit HU mapping using these criteria is shown in Figure 9.

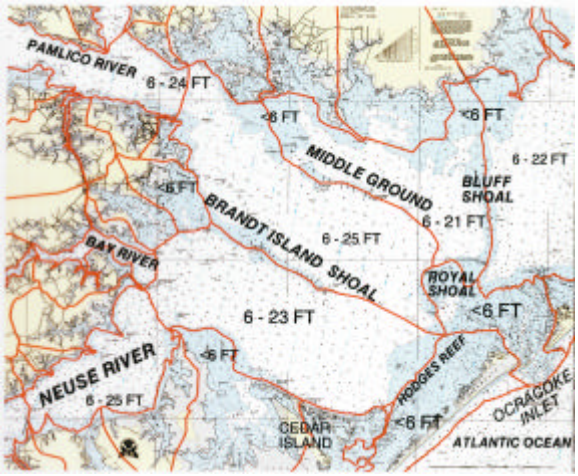

Figure 9. Bathymetric map illustrating proposed 14-digit HU delineations.

SUBMERGED SHOALS CLARIFY RIVER-BASIN BOUNDARIES

Knowledge gained from delineating HUs based on submerged topographic features clarified the interpretation of boundaries between river basins. For Example, the boundary along Brandt Island Shoal, Figure 9, justifies movement of the boundary between the Neuse and Tar-Pamlico Basins. This moves Bay River and adjacent estuarine areas into the Neuse Basin.

Delineation and Digitizing Methodology

OVERVIEW OF SECTION

This section of the proposal provides details on the considerations and methodology used to delineate open-water hydrologic units in estuarine areas. Source maps and map scales are discussed, as well as specifics on how units were actually delineated on the maps and digitized.

CONSISTENT BATHYMETRIC CHARTS

NOAA nautical charts in digital format were used for all open-water, estuarine HU delineations. These charts are compiled by NOAA using a selective set of available bathymetric points and are digitally scanned from stable base maps by Maptech, Inc. The six-foot contour on these maps is created by people who have access to all the bathymetric points. Dr. Randolph Ferguson, Chair of the Coastal Subcommittee, was instrumental in methodology development, and delineated all of the estuarine, open-water hydrologic units for this project. The digital charts used ranged in scale from 1:10,000 to 1:80,000, are Mercator Projection, and have a NAD83 horizontal datum and vertical datum of mean lower low water.

"HEADS UP" DIGITIZING

All HU open-water, estuarine delineations were digitized on screen (heads up) using ESRI ArcView GIS software. Validation testing of the heads up digitizing method produced RMS errors within National Map Accuracy Standards at the 1:24,000 scale. The ArcView HU shapefiles were converted to ArcInfo line coverages and are being merged with the revised statewide 14-digit hydrologic unit coverage.

DELINEATION METHODOLOGY

A minimal 14-digit estuarine HU area of 3,000 acres was adopted to maintain consistency with land-based delineations. However, several open-water polygons in Pamlico Sound, and one in Albemarle Sound, exceed the 40,000-acre upper limit. To maintain the hydrologic integrity of these mixing basins, the large polygons were not subdivided. In areas where there are long, narrow, open-water stretches, such as along the Intracoastal Waterway (ICWW) in southeastern North Carolina, the land-based HU was extended to subsume the channel, assuring drainage to a point. Around inlet areas the hydrologic unit was delineated to capture the geomorphic expression of the inlet's geologic structure. Barrier islands were defined by the 30-foot offshore shoreface contour and the 6-foot back-bay contour. This maintained the geologic integrity of the barrier island, focusing attention on the true island structure, rather than the ephemeral shoreline.

Justification and Recommendations

JUSTIFICATION FOR MODIFYING HUS

There are several strong justifications for modifying estuarine hydrologic units.

- *The open-water geomorphic methodology provides consistency with the land-based criteria: (1) drainage area delineations follow relic ridge lines (shoals); (2) the method assures drainage to a point (coastal inlet); and the stream network hierarchy is preserved.*
- *The consistent delineation techniques provide a defensible, science-based methodology.*
- *These changes reconcile differences between federal and state mapping and present a common, shared hydrologic framework to the citizens.*
- *By restoring hydrologic integrity to these mapping units, increased scientific utilization of these units will provide management a more defensible basis for policy decisions and resource allocation.*
- *With mandated changes due to certification already occurring, now is the time to resolve the discrepancies between land and open-water delineation methods.*
- *Recent advances in computer technology will facilitate changes to existing HU designations.*

TWO RECOMMENDATIONS

To correct certification problems, the Coastal Subcommittee recommends two changes in the way 14-digit hydrologic units are currently delineated in the open-water areas of North Carolina's estuaries.

1. *Modify current estuarine delineations to comply with the geomorphic criteria set forth in this report; and*
2. *Modify existing 8-digit and 11-digit HU associations to maintain continuity between headwater areas and discharge to the ocean.*

The implications of recommendation 2 are discussed in the following paragraph.

MAJOR-BASIN MODIFICATION

The major-basin, or unit-boundary problem, is discussed on page 7 and illustrated in Figure 6. The Subcommittee recommends that a new White Oak River Basin designation be created to include those rivers and streams in southeastern North Carolina that drain directly to the ocean. This proposal is illustrated in Figure 10. The New and White Oak Rivers, and Core Sound, coincide with the paleodrainage patterns illustrated in Figure 8, and such designation would bring compatibility between federal and state network classification schemes in this region. The State of North Carolina already recognizes the White Oak as a distinct river basin.

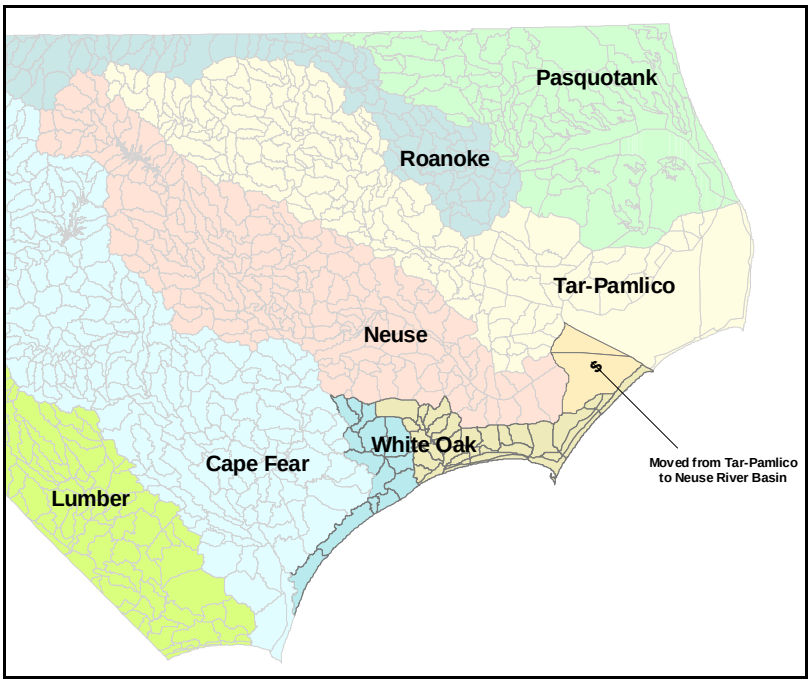

Figure 10. Proposed changes to river-basin associations.

SPECIFIC CHANGES PROPOSED

The Coastal Subcommittee proposes three distinct changes to the federal and state stream-network classification schemes currently used in North Carolina.

1. *Change the 6-digit river-basin designation for 14-digit units 03020106050010 and 03020105090012 from the Tar-Pamlico to the Neuse River Basin.*
2. *Change the 6-digit river-basin designation for all 14-digit units in Core and Bogue Sounds and the White Oak River from Tar-Pamlico to the new White Oak Basin.*
3. *Change the 6-digit river-basin designation for 14-digit units draining the New River and units draining directly to the ocean, as shown in Figure 10, from the Cape Fear to the new White Oak River Basin.*

COMMENTS REQUESTED

The Coastal Subcommittee is seeking comments on these proposed changes to the hydrologic-unit delineations of North Carolina's estuarine waters. Please convey any comments or suggestions to the following individuals.

comments on methodology

Randy Ferguson (NOAA)
randy.ferguson@noaa.gov
252.728.8764

comments on impacts changes may have

Sherman Biggerstaff (NRCS)
sbiggerstaff@nc.nrcs.usda.gov
919.873.2132

comments on this document

Ted Mew (DENR DWQ GW)
Ted.Mew@ncmail.net
919.715-61822

REFERENCES

Natural Resources Conservation Service (USDA) 1995a. *North Carolina cooperative hydrologic unit river basin study*. Raleigh, NC.

Natural Resources Conservation Service (USDA), 1995b (revised 2000). *Guidelines for mapping and digitizing hydrologic units.* National Instruction 170-304.

U.S. Geological Survey, 1974. *Hydrologic unit map – 1974 state of North Carolina*.